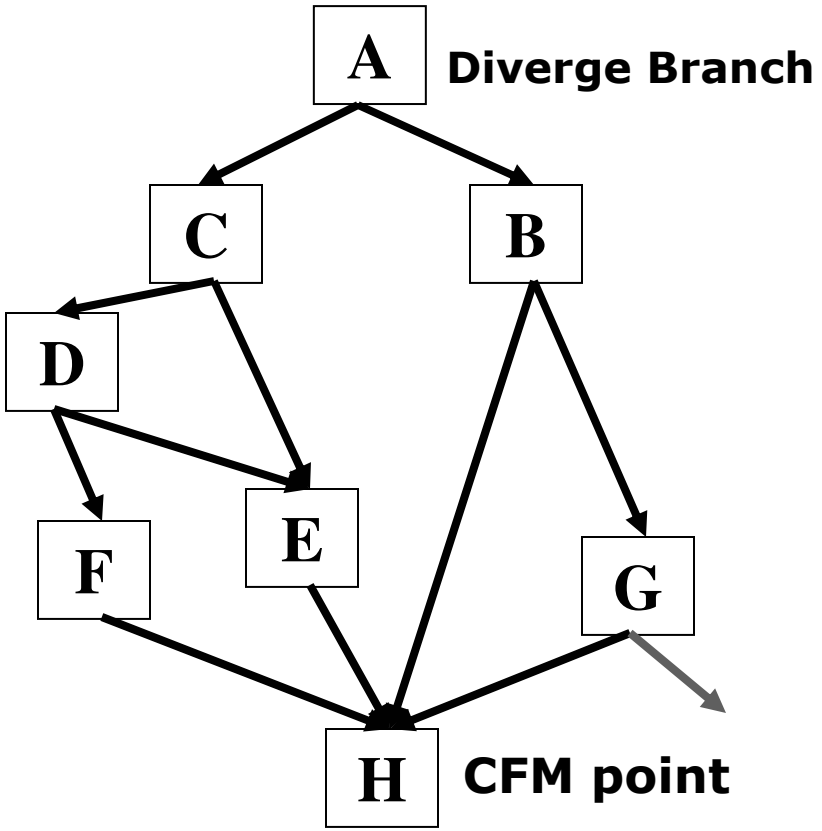
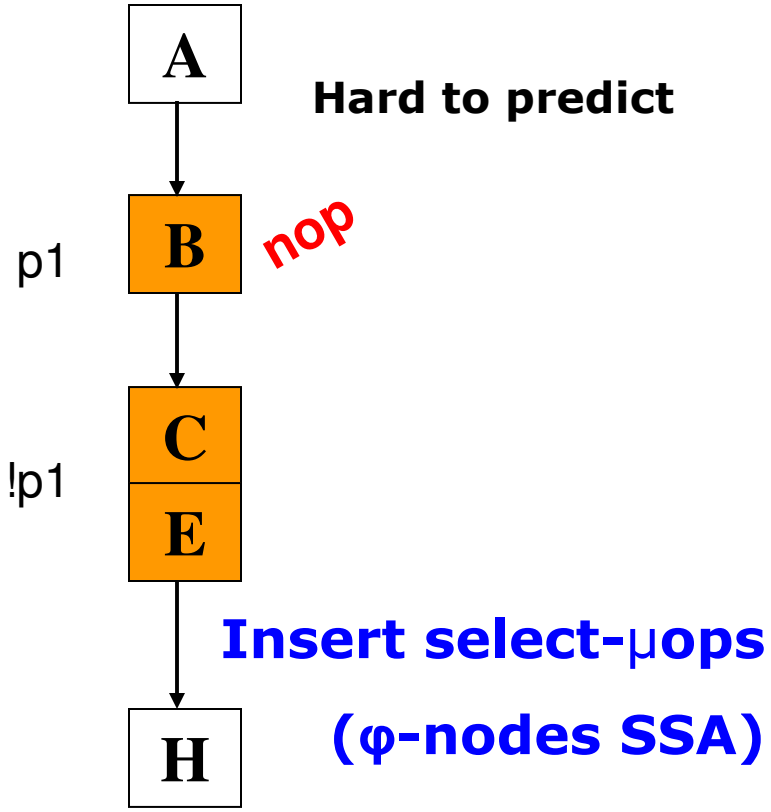




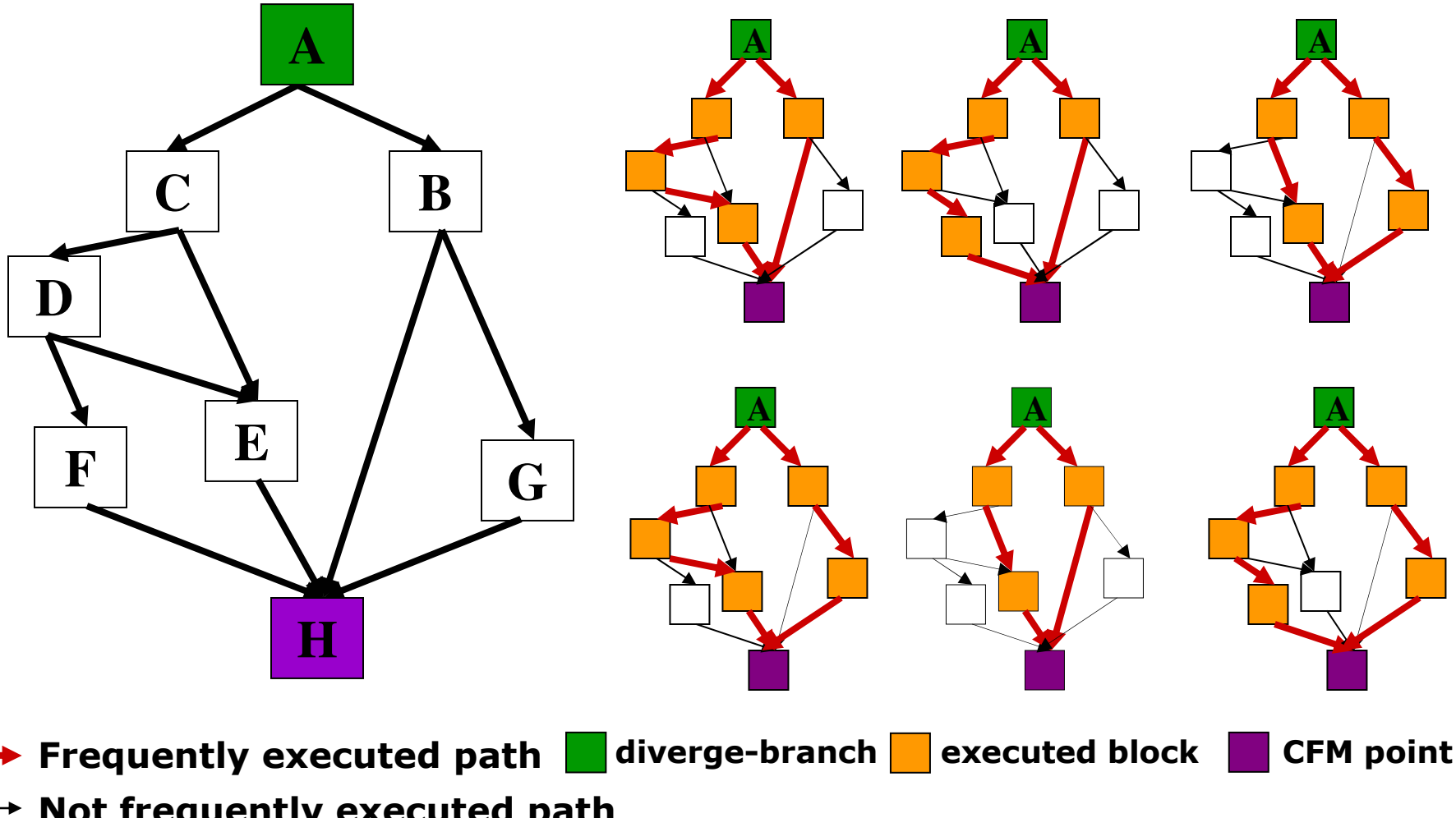
Frequently executed path

Not frequently executed path

Hard to predict path

Diverge-Merge Processor (DMP)

[MICRO 2006, TOP PICKS 2007]



Profile-Assisted Compiler Support for Dynamic Predication in Diverge-Merge Processors

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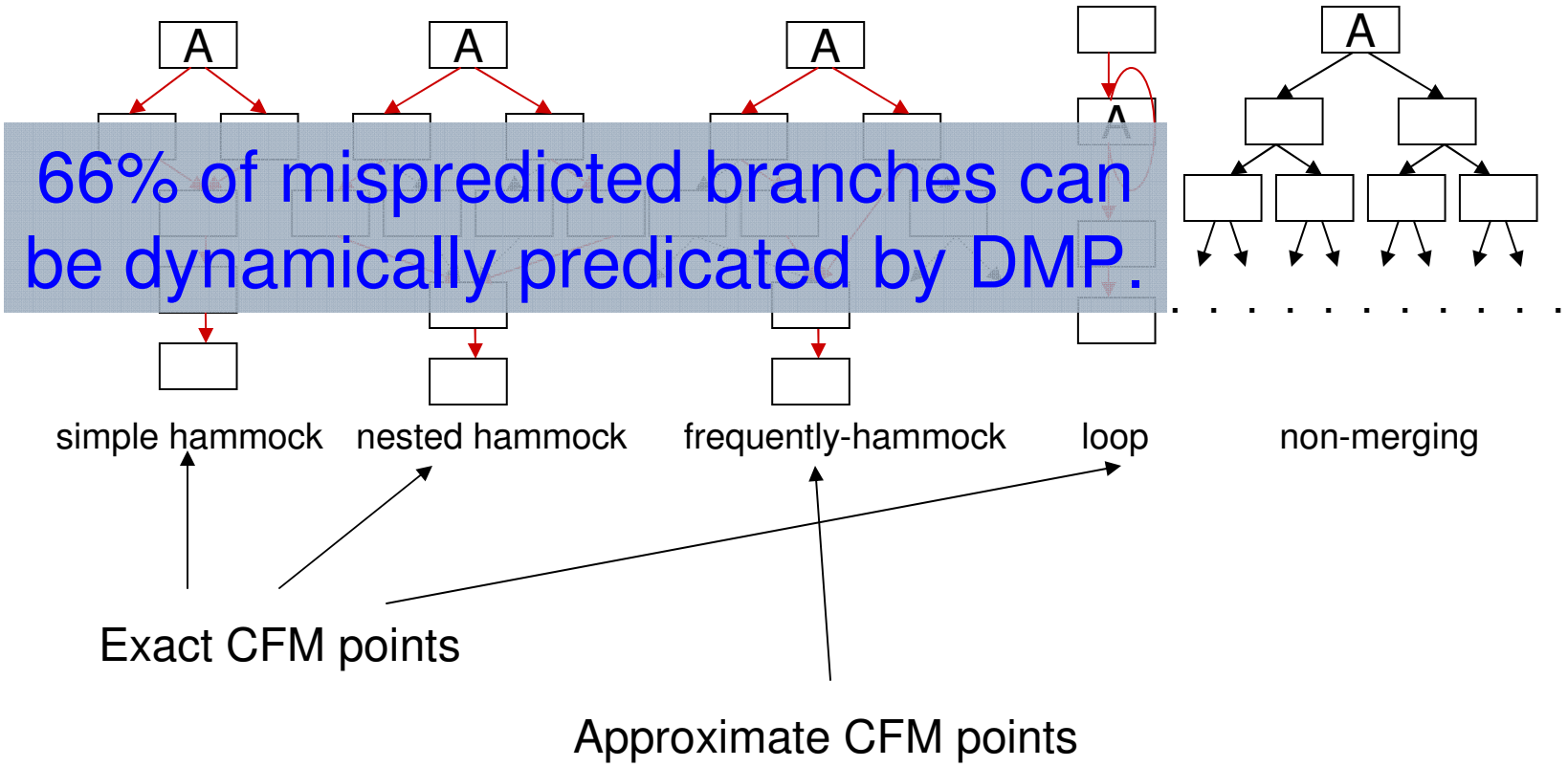
Control-Flow Graphs



Diverge-Merge Processor (DMP)

- DMP can dynamically predicate complex branches (in addition to simple hammocks).
- The compiler identifies
  - Diverge branches
  - Control-flow merge (CFM) points
- The microarchitecture decides when and what to predicate dynamically.

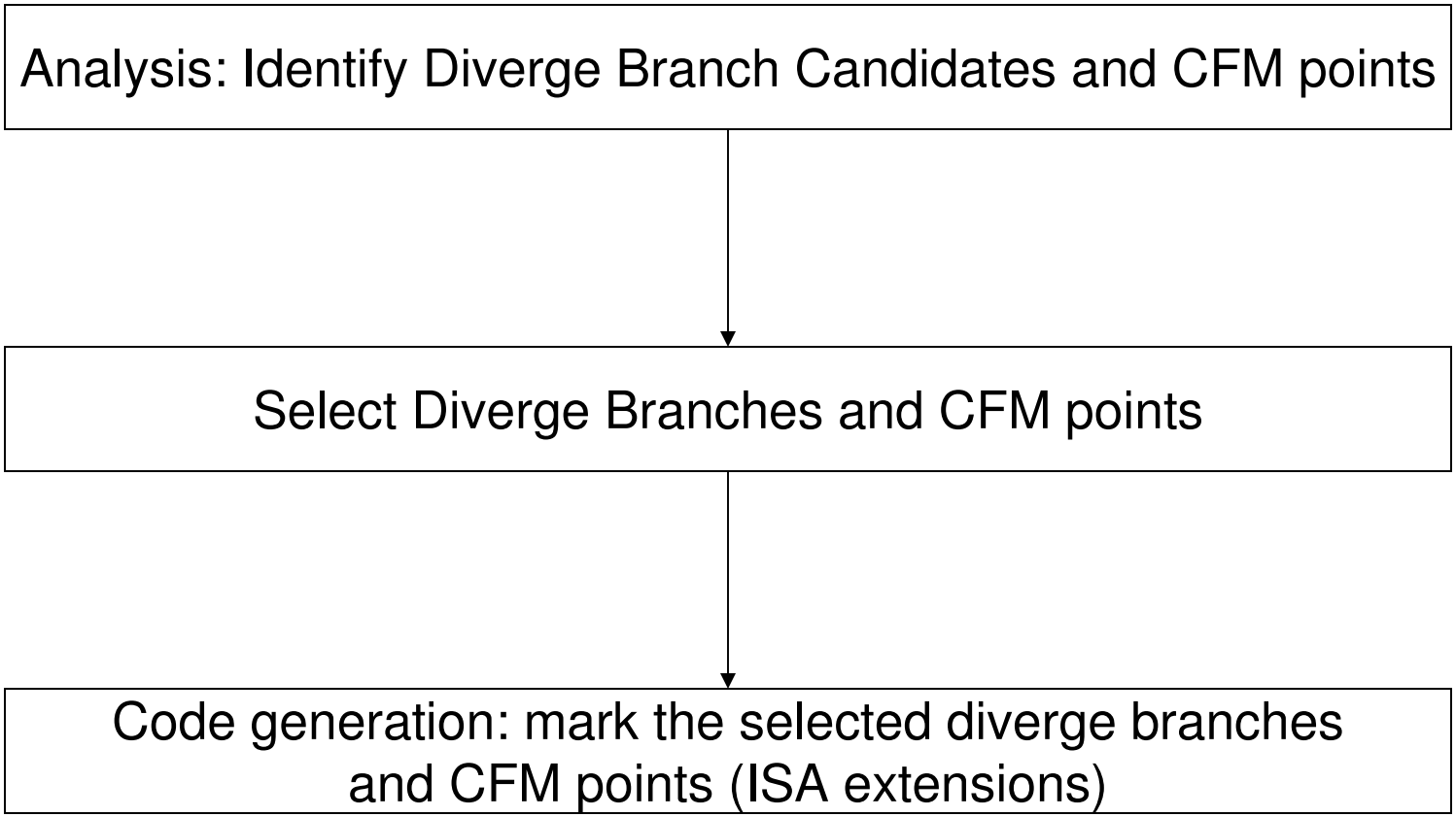
Why hardware *and* compiler?

- Compiler-centric solution (static predication):
  predicated ISA, not adaptive,
  applicable to limited CFG.

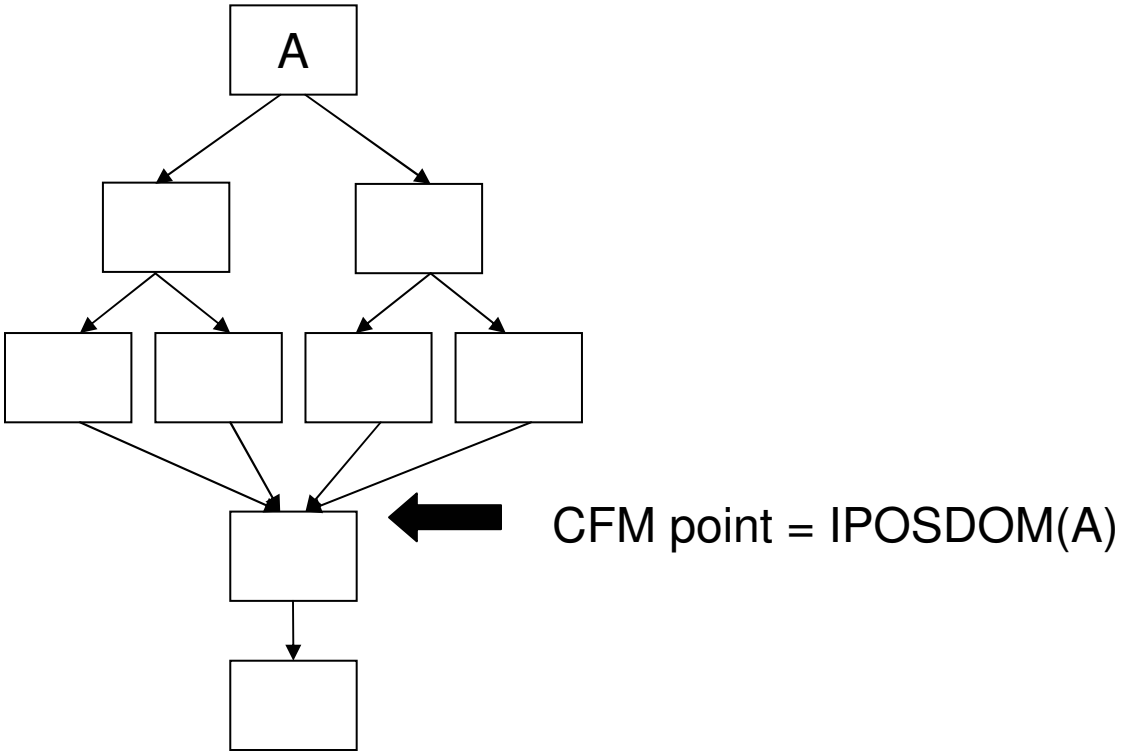
- Microarchitecture-only solution:
  complex, expensive, limited in scope.

- Compiler-microarchitecture interaction
  - Each one does what it is good at.

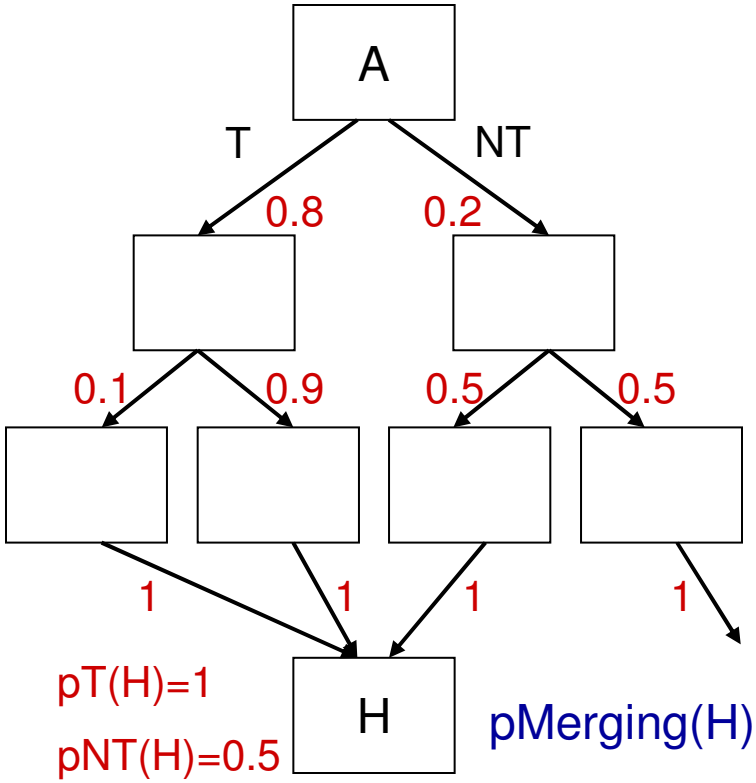
Compiler Support



Simple/Nested Hammocks: Alg-exact



Frequently-Hammocks: Alg-freq



- Use edge-profiling frequencies

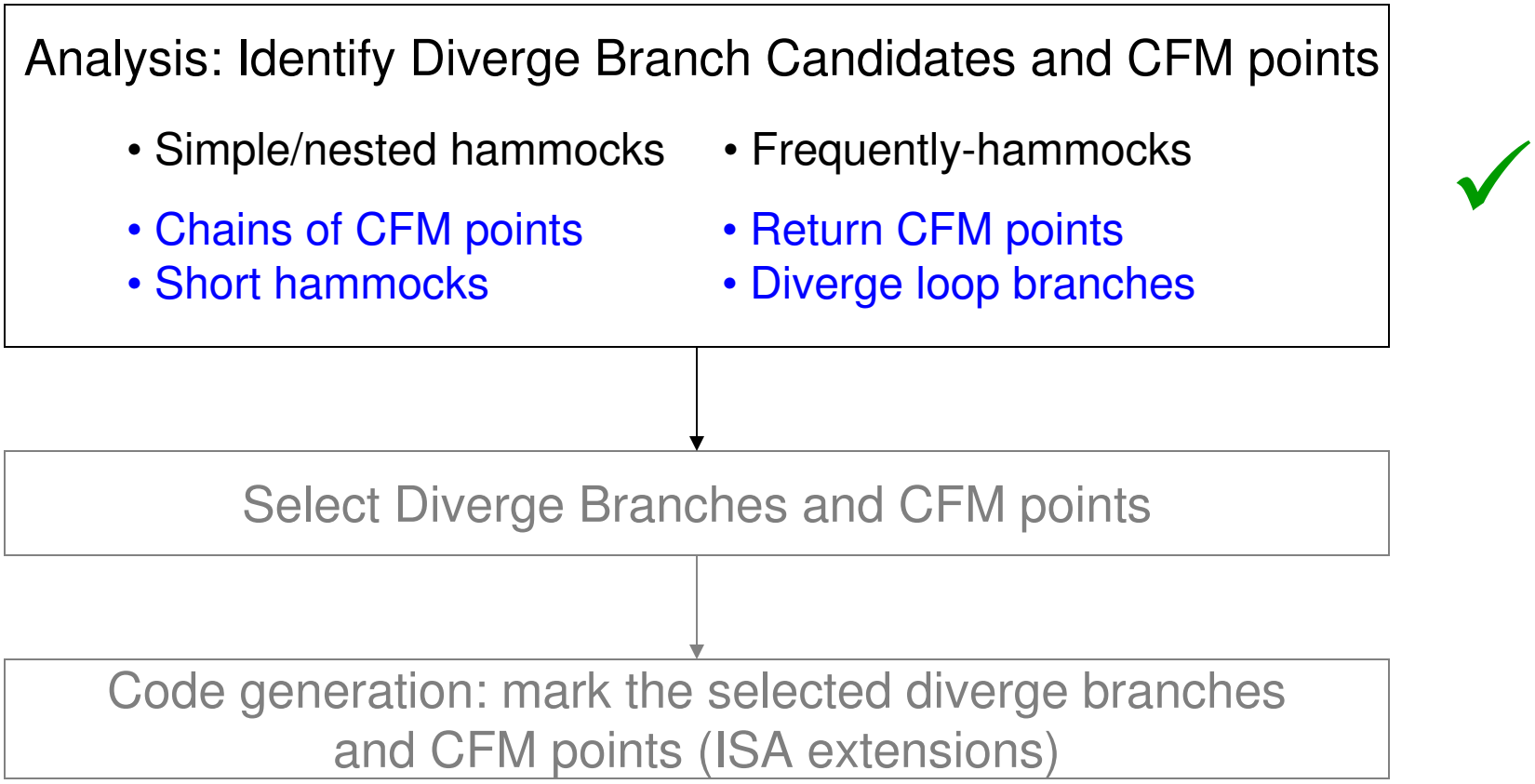
pT(X): conditional probability of reaching basic block X if branch A is taken

pNT(X): conditional probability of reaching basic block X if branch A is not taken

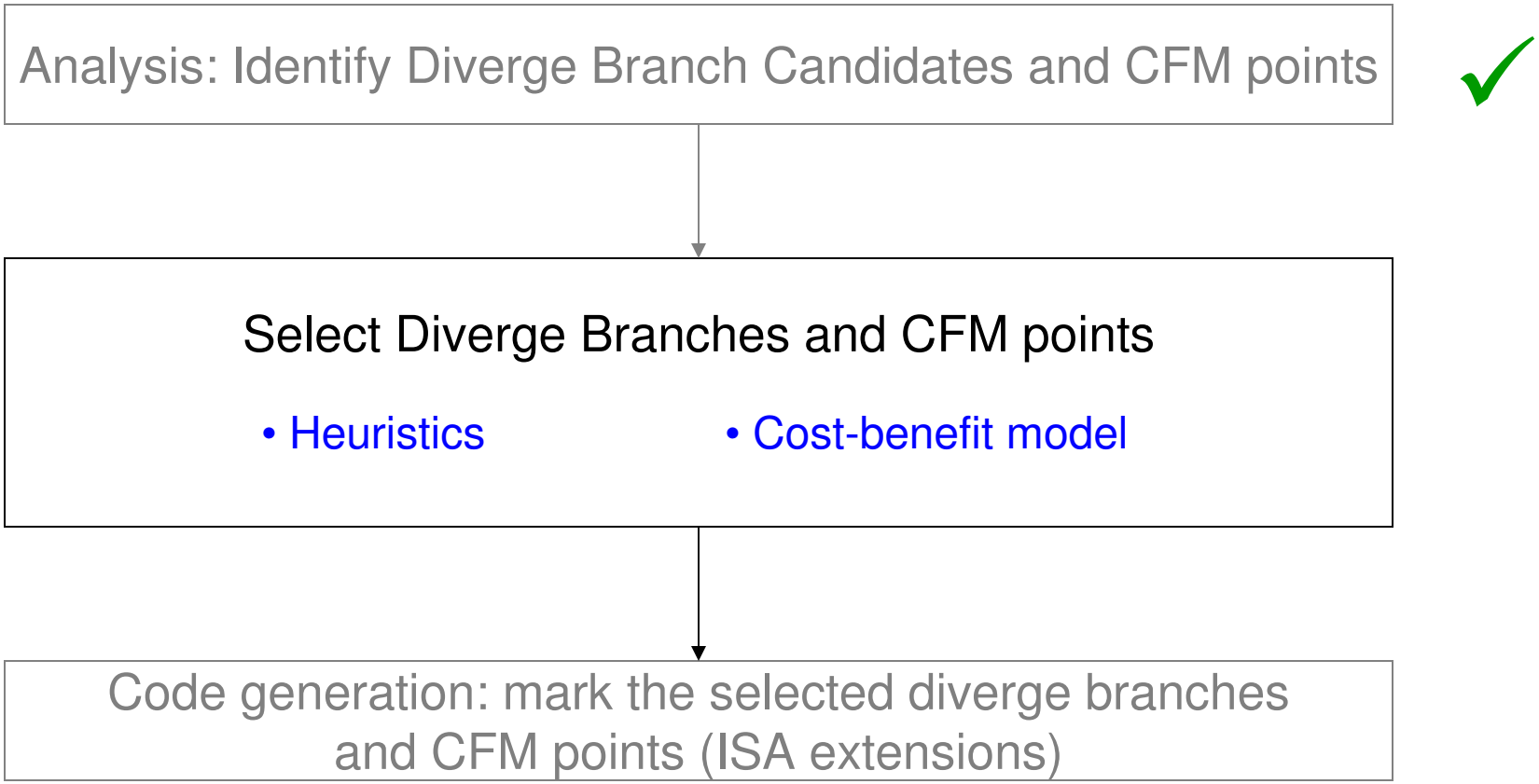
- Stop at IPOSDOM or MAX_INSTR
- Compute pMerging(X) = pT(X) * pNT(X)

pMerging(H) = 1 * 0.5 = 0.5 ⟵ CFM point candidate !

Compiler Support



Compiler Support



Heuristics-Based Selection

Motivation:

minimize overhead: wrong path

maximize benefit: control-independence

Do not select:

- CFM points too far from the diverge-branch
- Hammocks with too many branches on each path
- Approximate CFM points with a low probability of merging

Cost-Benefit Model-Based Selection

Confidence	Estimation	Cost	Benefit	Compared to baseline
High	-	-	-	Same
Low	Inaccurate	Overhead	None	Lose
	Accurate	Overhead	No flush	possibly WIN

A = accuracy of the conf. estimator = mispredicted / low_conf.

cost = (1 – A) x overhead
+ A x (overhead – misprediction_penalty)

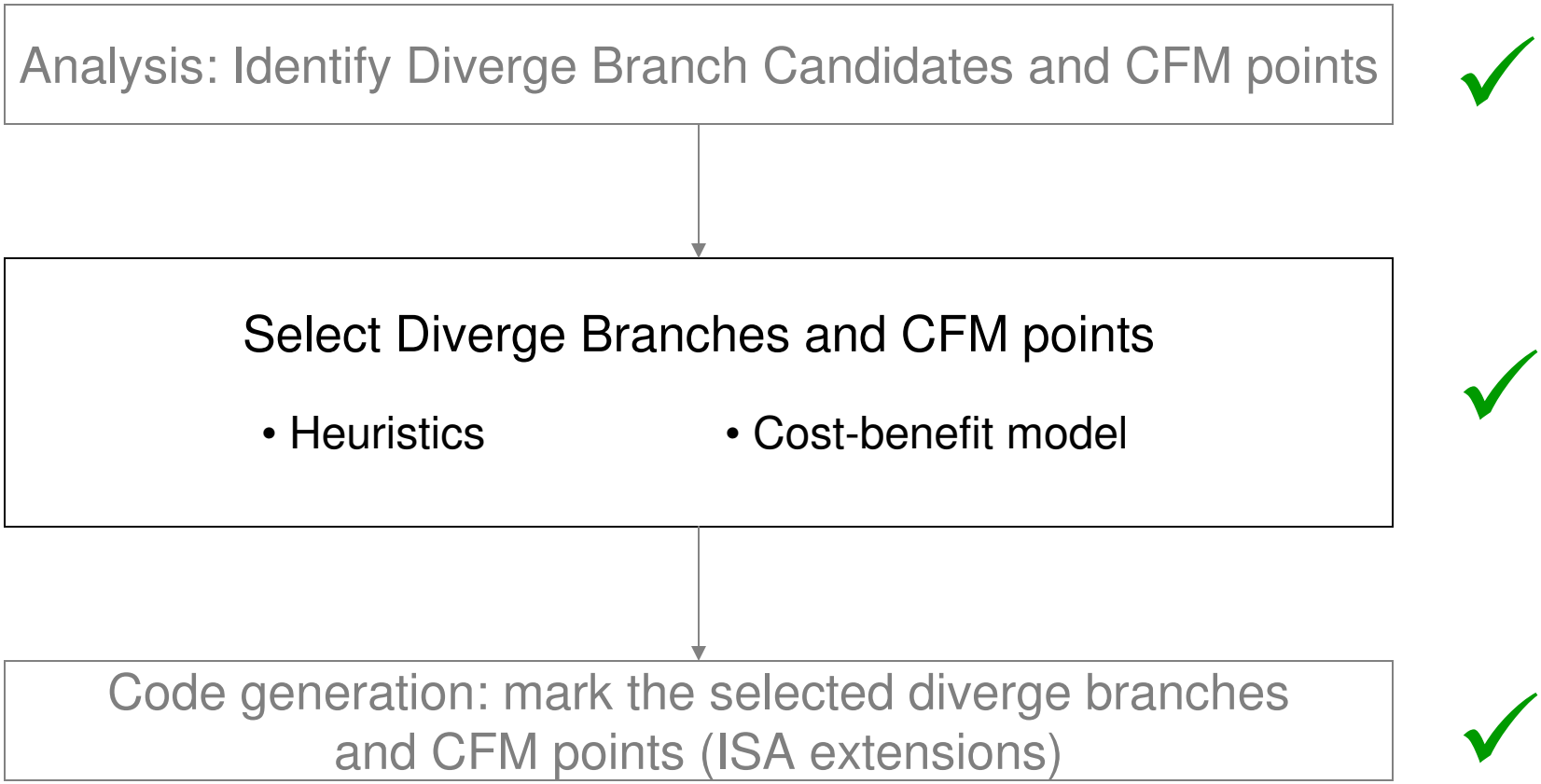
Cost-Benefit Model-Based Selection

Select if *cost < 0*

A = accuracy of the conf. estimator = mispredicted / low_conf.

cost = (1 – A) x overhead
+ A x (overhead – misprediction_penalty)

Compiler Support

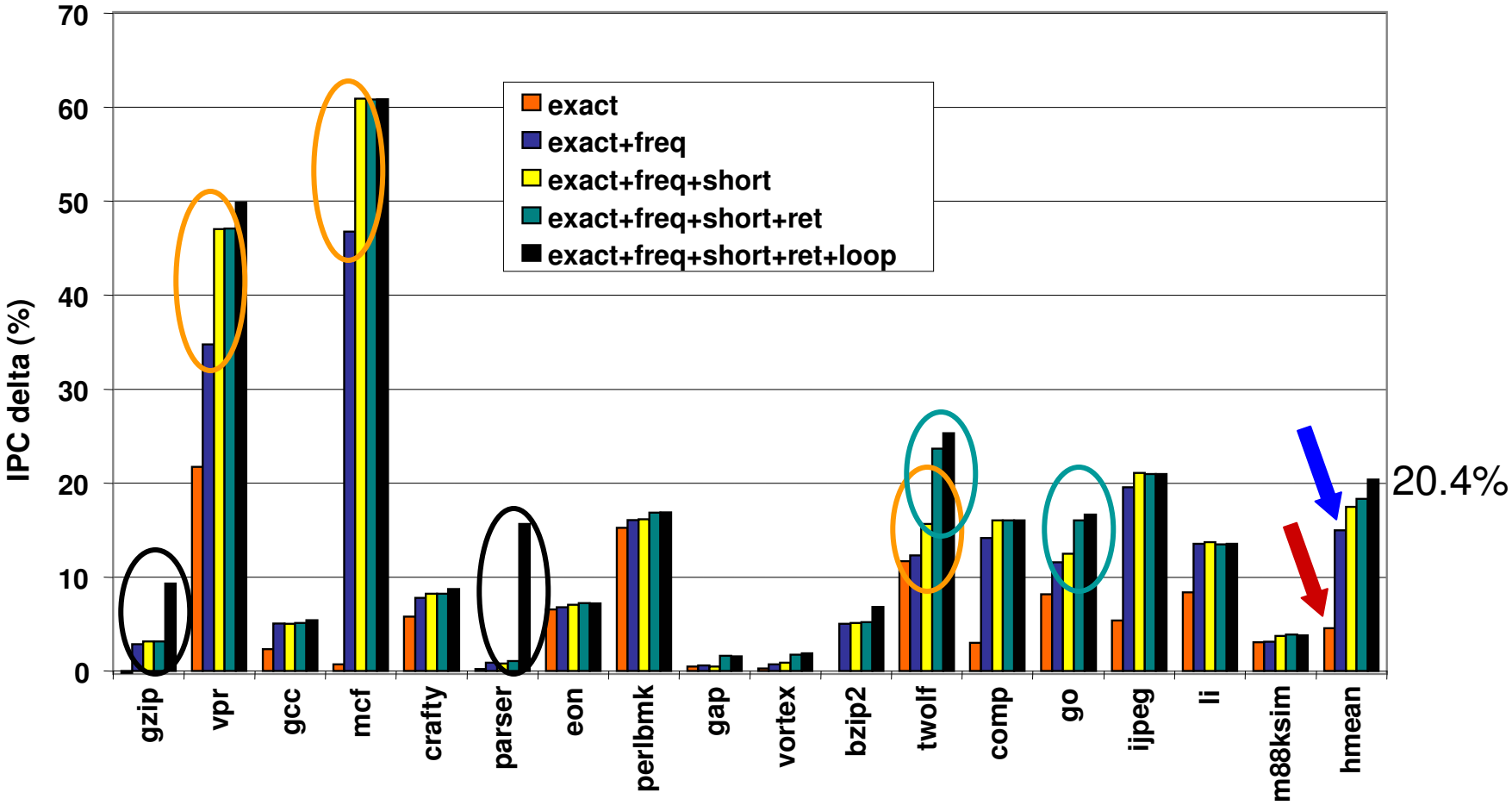


Methodology

- All compiler algorithms implemented on a binary analysis and annotation toolset.

- Cycle-accurate execution-driven simulation of a DMP processor:
  - Alpha ISA
  - Processor configuration
    - 16KB perceptron predictor
    - Minimum 25-cycle branch misprediction penalty
    - 8-wide, 512-entry instruction window
    - 2KB 12-bit history enhanced JRS confidence estimator
    - 32 predicate registers, 3 CFM registers
  - 12 SPEC CPU 2000 INT, 5 SPEC 95 INT

Heuristic-Based Selection



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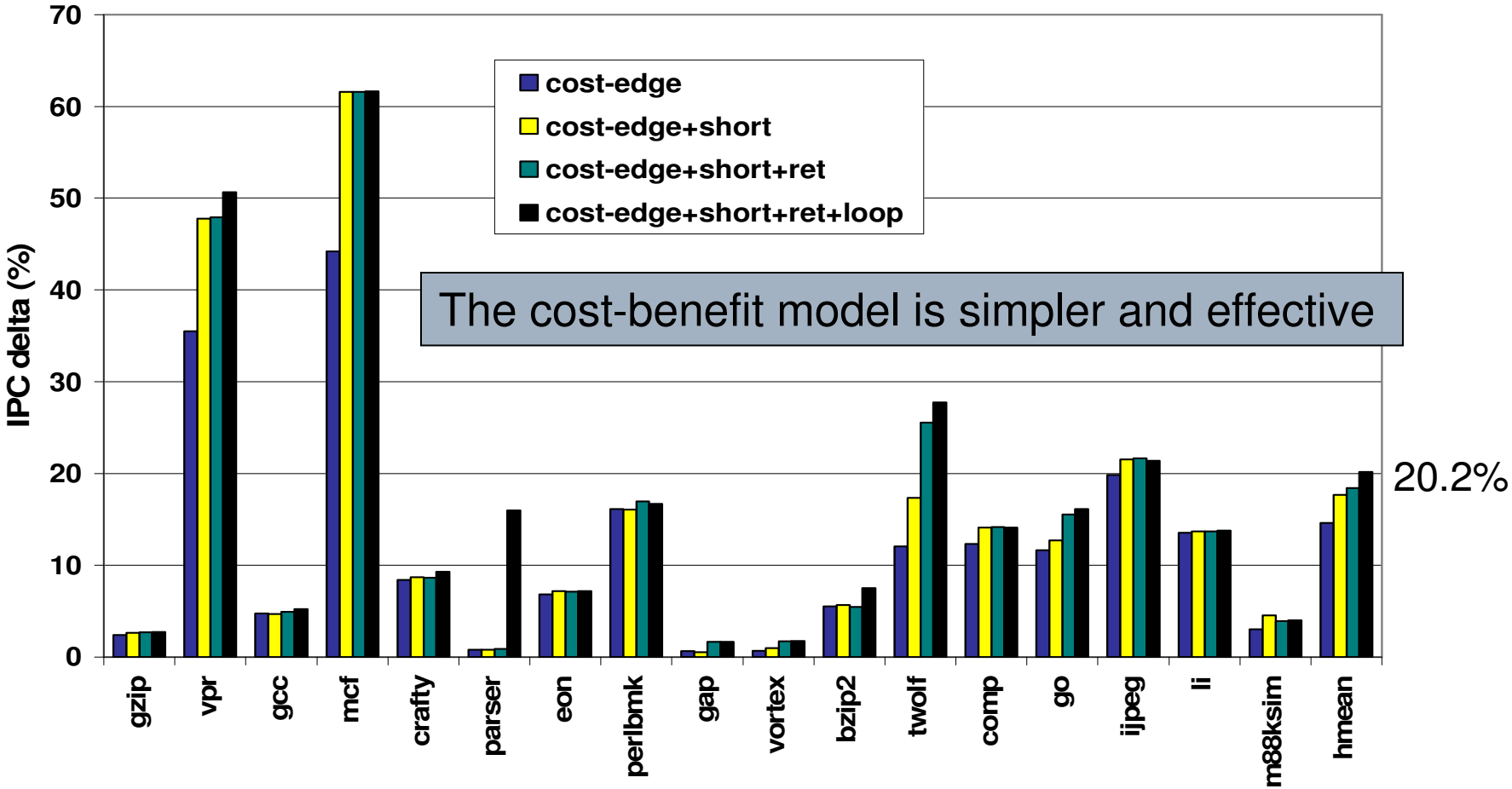
Cost-Benefit-Based Selection



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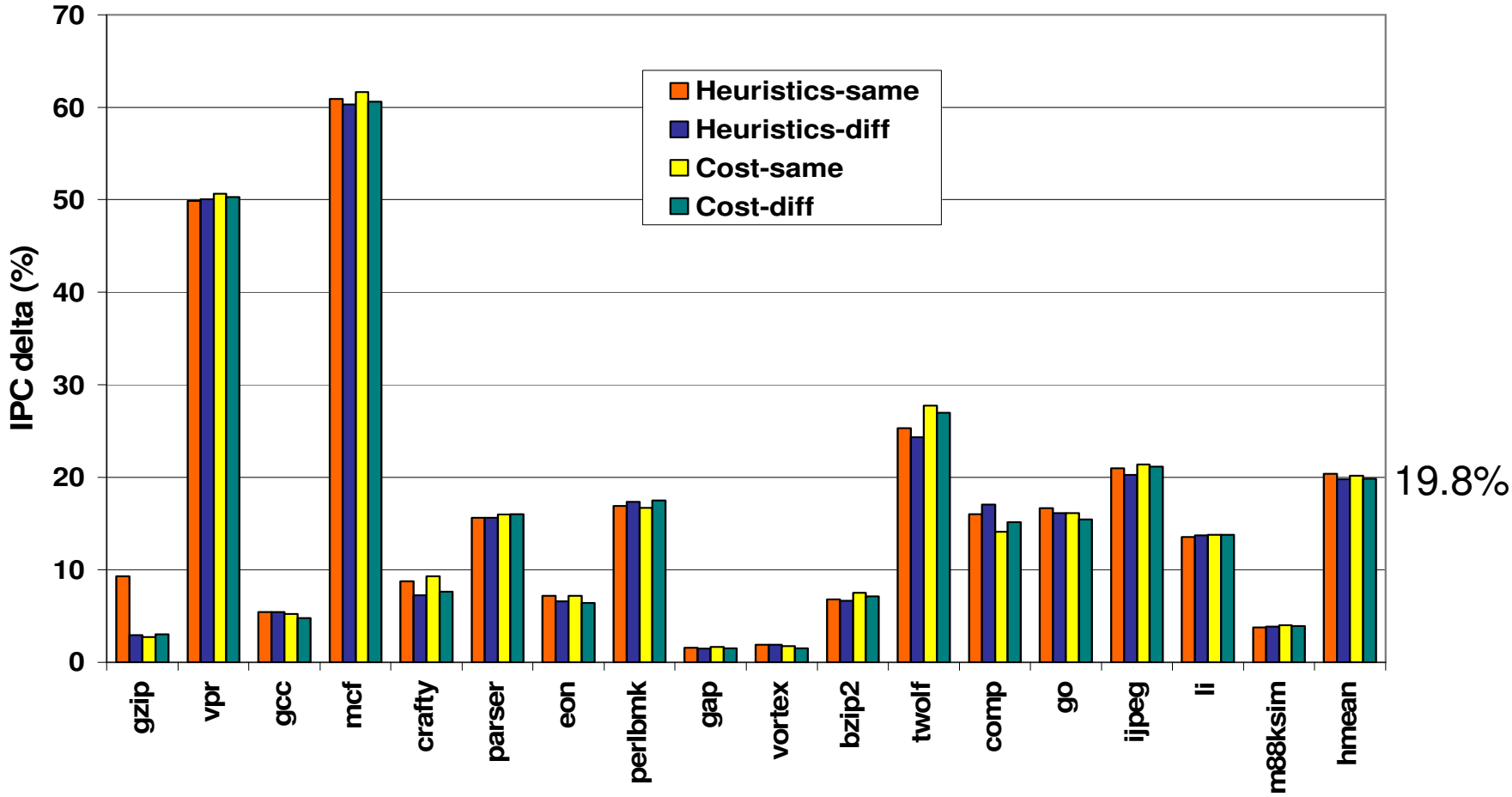
Input Set Effects



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Conclusion

- Compiler-microarchitecture interaction is good!
- DMP exploits frequently-hammocks.
- We developed new algorithms that select beneficial diverge-branches and CFM points.
- We proposed a new cost-benefit model for dynamic predication.
- DMP and our algorithms improve performance by 20%.

Thank You!

Questions?